



# **Impact of CO<sub>2</sub> Intrusion into USDWs, the Vadose Zone, and Indoor Air**

**DOE/EPA Collaborative Review  
Tracking Geologically Sequestered CO<sub>2</sub>:  
Monitoring, Verification, & Accounting (MVA), Simulation and Risk  
Assessment**

**Pittsburgh, PA  
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# 1. Development of Methods to Evaluate Gas Intrusion into Buildings from Geological Sequestration of CO<sub>2</sub> Using Natural and Anthropogenic Analogues

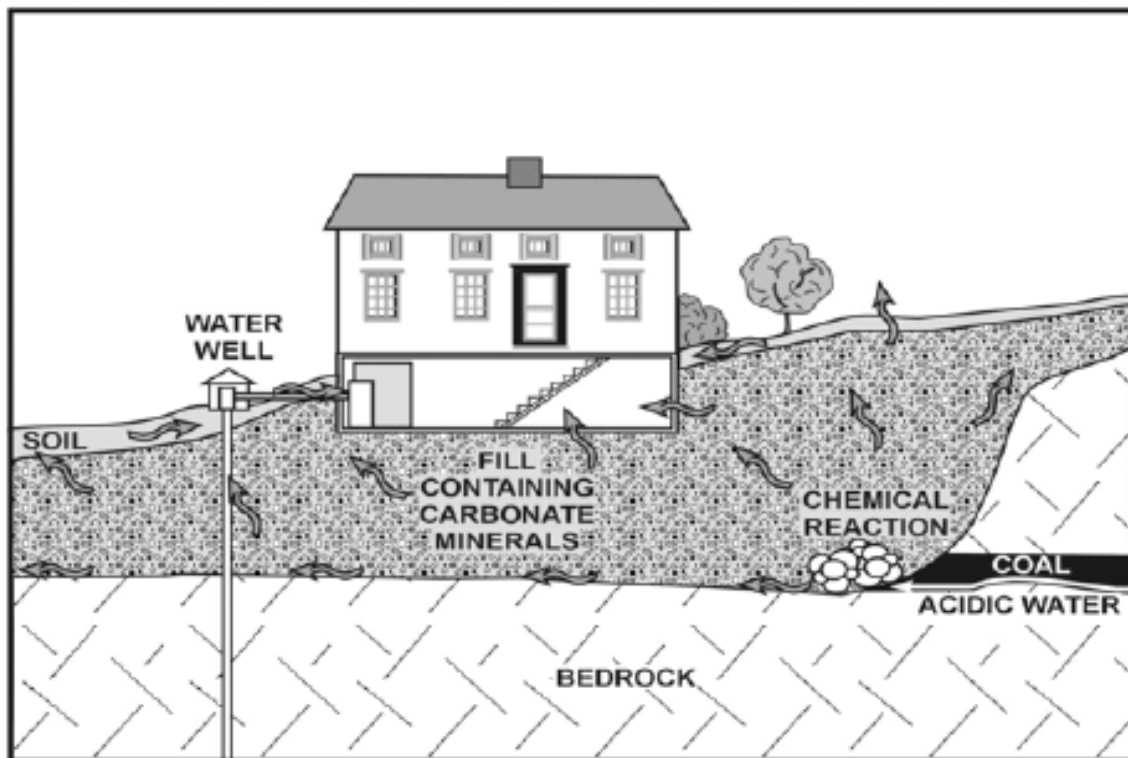
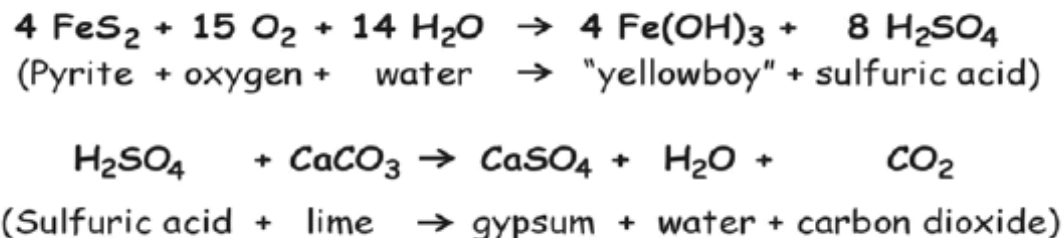
Elevated levels of CO<sub>2</sub> in ground water and the vadose zone will cause displacement of O<sub>2</sub> and intrusion of CO<sub>2</sub> into buildings.

## Overall Objective

Develop a protocol to distinguish natural and anthropogenic causes of CO<sub>2</sub> intrusion into buildings.

Increase public acceptance?

**Source: Pittsburgh  
Geologic Survey**



## Study Location - Valley Center, KS



During a period of heavy precipitation on September 13, 2008, low O<sub>2</sub> and elevated CO<sub>2</sub> levels were measured in indoor air in a number of homes in and around Valley Center, Kansas. The lowest and highest O<sub>2</sub> and CO<sub>2</sub> concentration measured in indoor air was 10% and 7%, respectively.

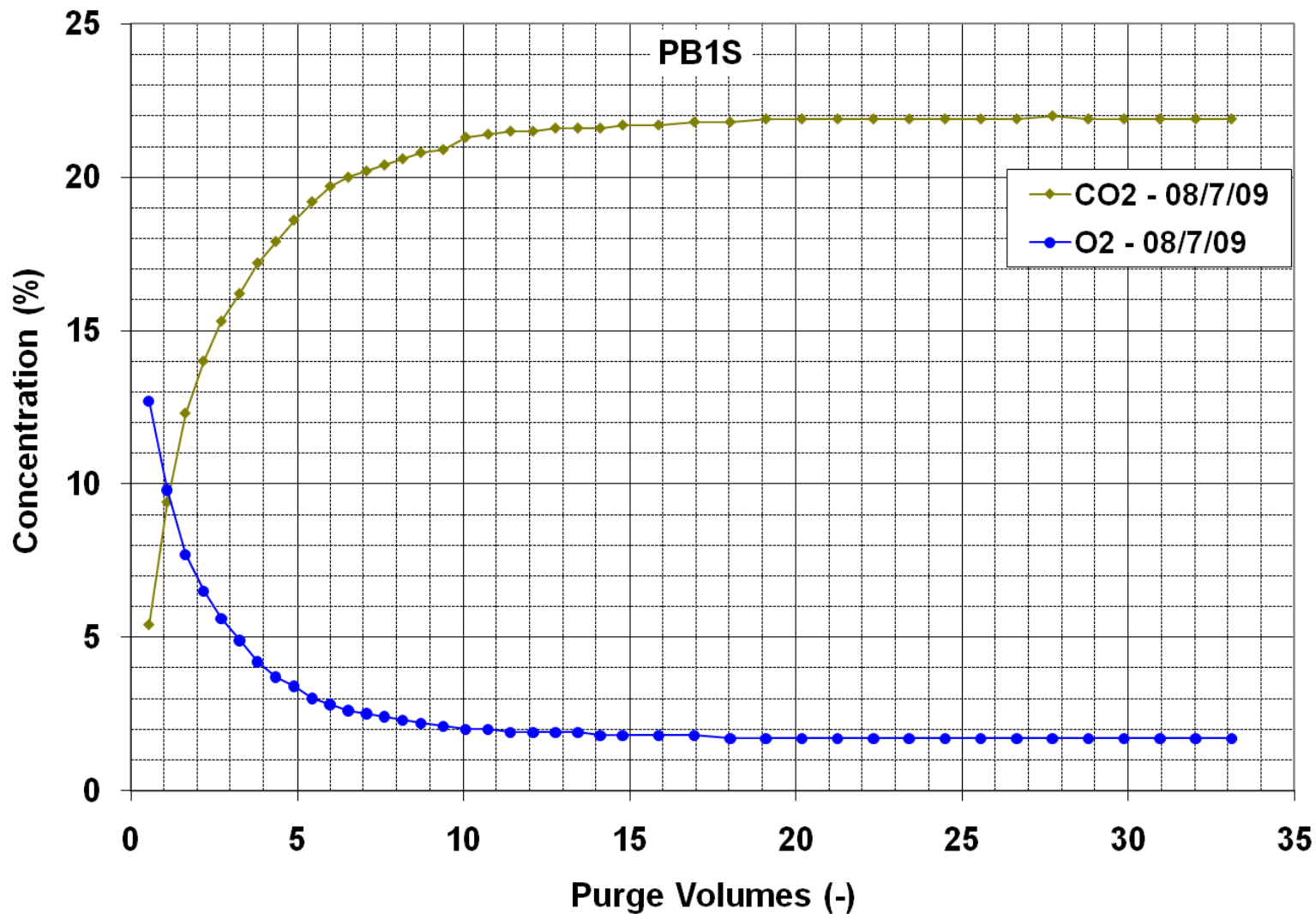


## Site-Specific Objectives

- Determine geochemical reactions causing observation of elevated  $\text{CO}_2$  and depressed  $\text{O}_2$  in soil gas;
- Determine the primary point(s) of entry (e.g., sump basins) of soil gas into homes;
- Determine an effective means of eliminating or minimizing intrusion of oxygen displacing soil-gases ( $\text{N}_2$  and  $\text{CO}_2$ ) during heavy precipitation events.

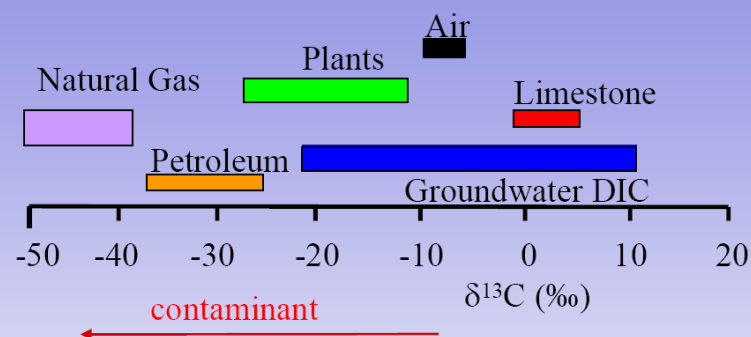
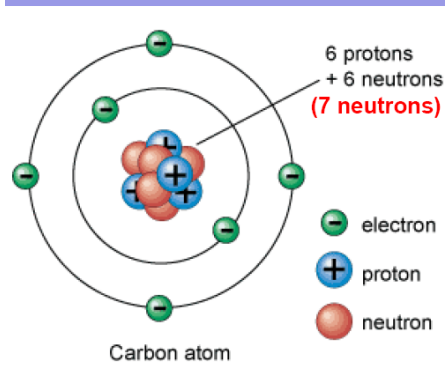


## Typical Soil-Gas Profile at Valley Center



# Use of Carbon Isotopes to Identify Thermogenic/Microbial Origin of CO<sub>2</sub> in Ground Water and Soil Gas

## Stable Isotope Nomenclature



Depleted

Enriched

**Source: Fessenden et al. (2008)**

$$\delta^{13}\text{C}_{\text{CO}_2} \text{ ‰} = \left[ \frac{^{13}\text{C}/^{12}\text{C} \text{ sampled}}{^{13}\text{C}/^{12}\text{C} \text{ standard}} - 1 \right] \times 1000$$

$$\Delta^{14}\text{C}_{\text{CO}_2} \text{ ‰} = \left( \frac{^{14}\text{C}/^{12}\text{C} \text{ sample}}{^{14}\text{C}/^{12}\text{C} \text{ standard}} - 1 \right) \times 1000$$



## Primary Points of Entry – Tile Drains/Sump-Basin ?



# Tile Drains Connected to Sump Basins





# Primary Points of Entry/Evaluation of Mitigation Techniques

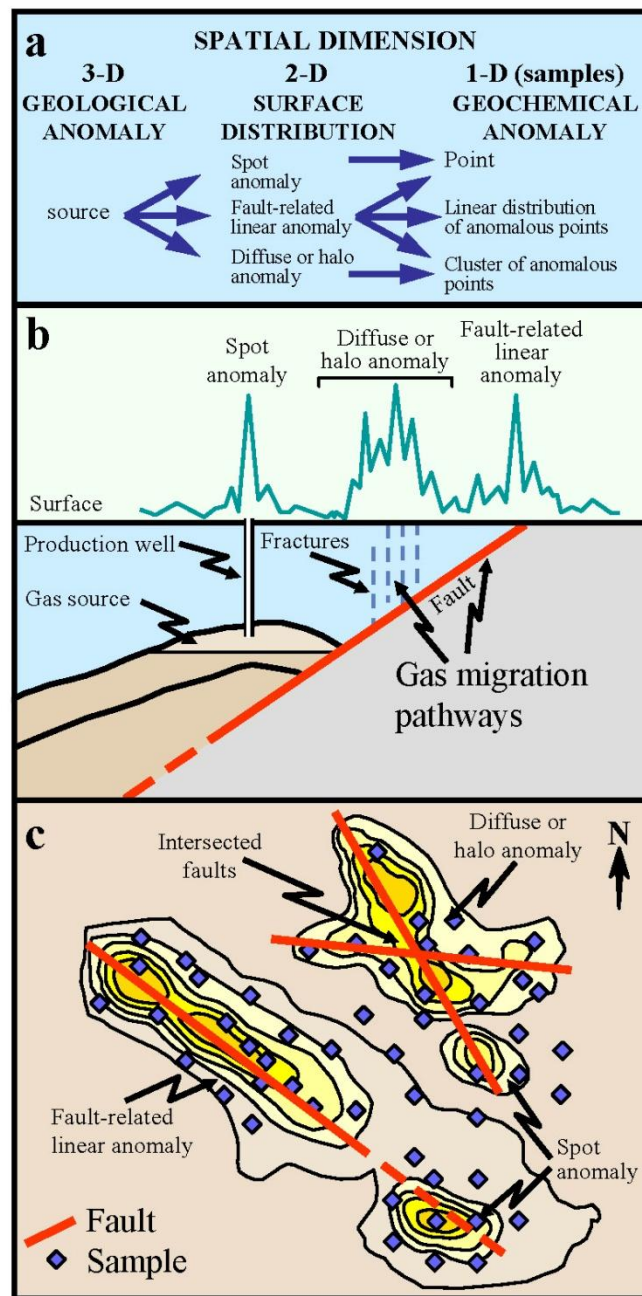
- Install radon mitigation systems
- Conduct blower door tests



## 2. Use of Soil-Gas and Ground-Water Monitoring to Evaluate Leakage from Well Penetrations and Faults at Anthropogenic Analogues

The objective of this research effort is to evaluate the usefulness of near-surface (< 1000 ft) soil-gas and ground-water measurements to detect the potential for leakage from well penetrations prior to injection and leakage during injection of CO<sub>2</sub>.

Gas and brine migration through well penetrations would have a spot anomaly whereas gas migration through faults and fractures would be expressed as a linear trend or diffuse anomaly.



# Soil-Gas Sampling Near Well Penetrations

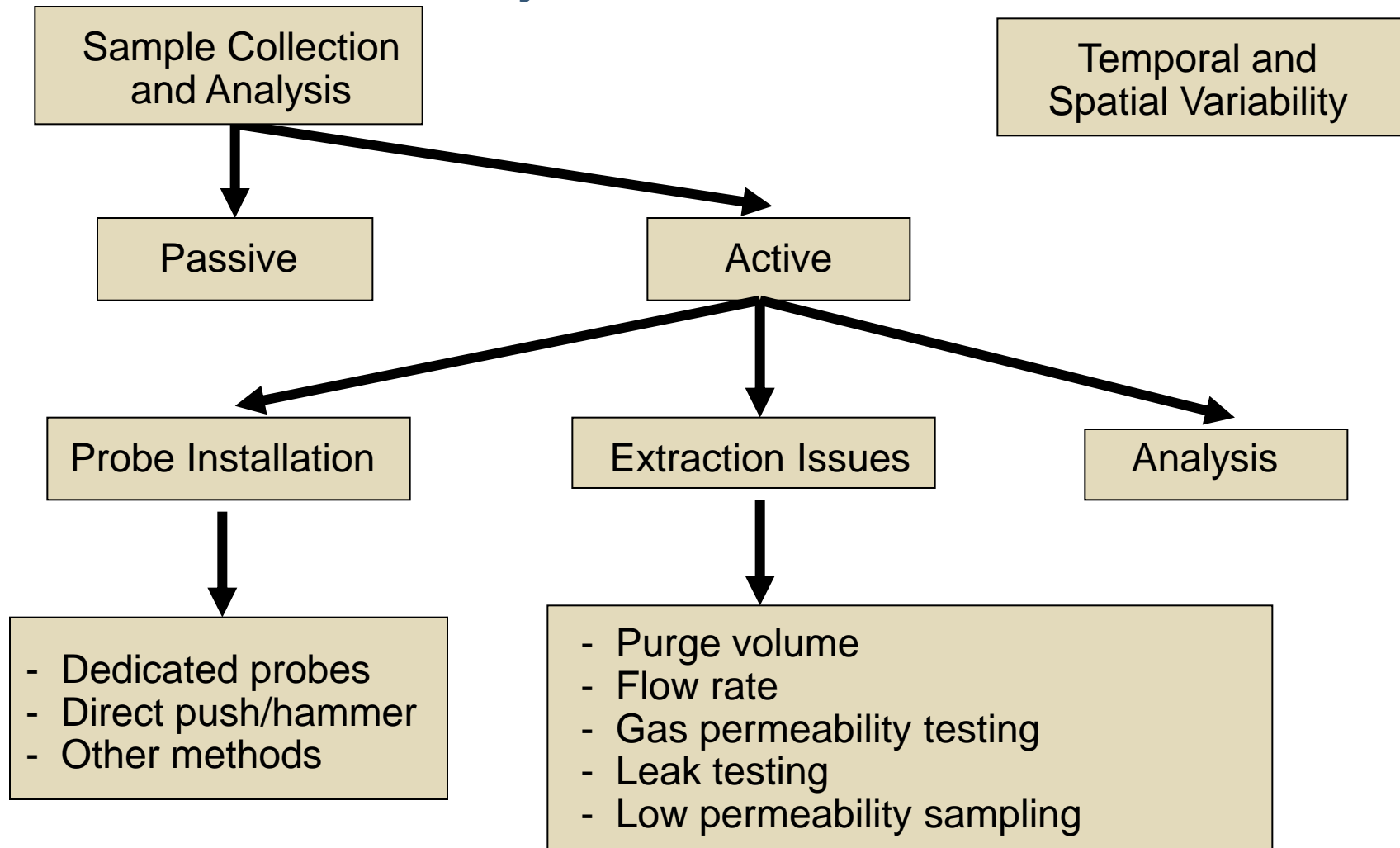
Gas and brine migration into a USDW could be accompanied by measurable alteration in pH, major ions, and potential mobilization of hazardous inorganic compounds.

Release of gas into the vadose zone could be accompanied by compositional changes in soil gas (e.g., CH<sub>4</sub>, C<sub>2</sub>-C<sub>4</sub> hydrocarbons, CO<sub>2</sub>, δ<sup>13</sup>C, Δ<sup>14</sup>C, H<sub>2</sub>, He, H<sub>2</sub>S, <sup>222</sup>Rn).





### 3. Method Development on Soil-Gas Sampling to Support Research Objectives on GS



# Simultaneous Leak, Purge, and Gas Permeability Testing

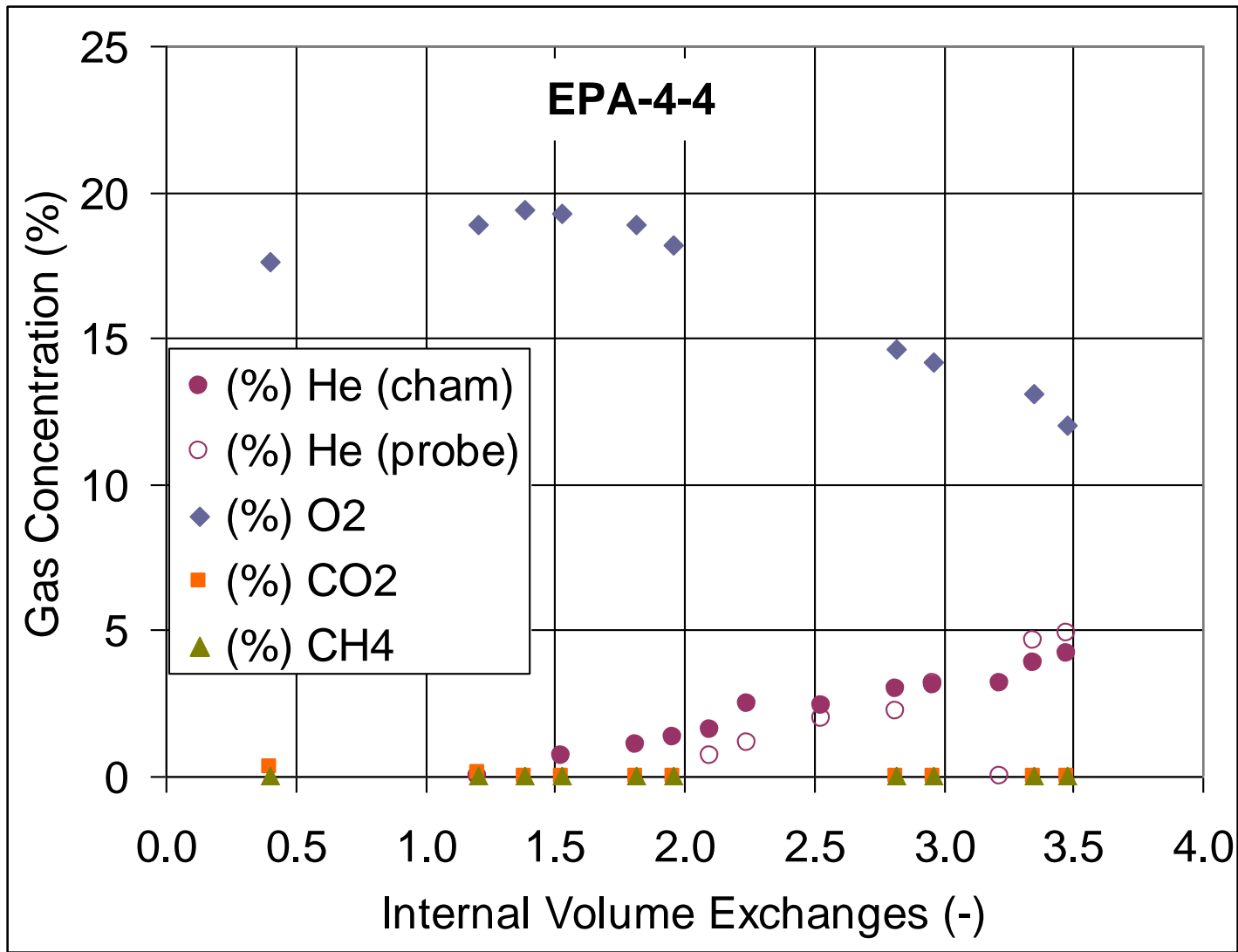


$$C = \frac{2bL}{r_w^2 \ln r_{atm}/r_w}$$

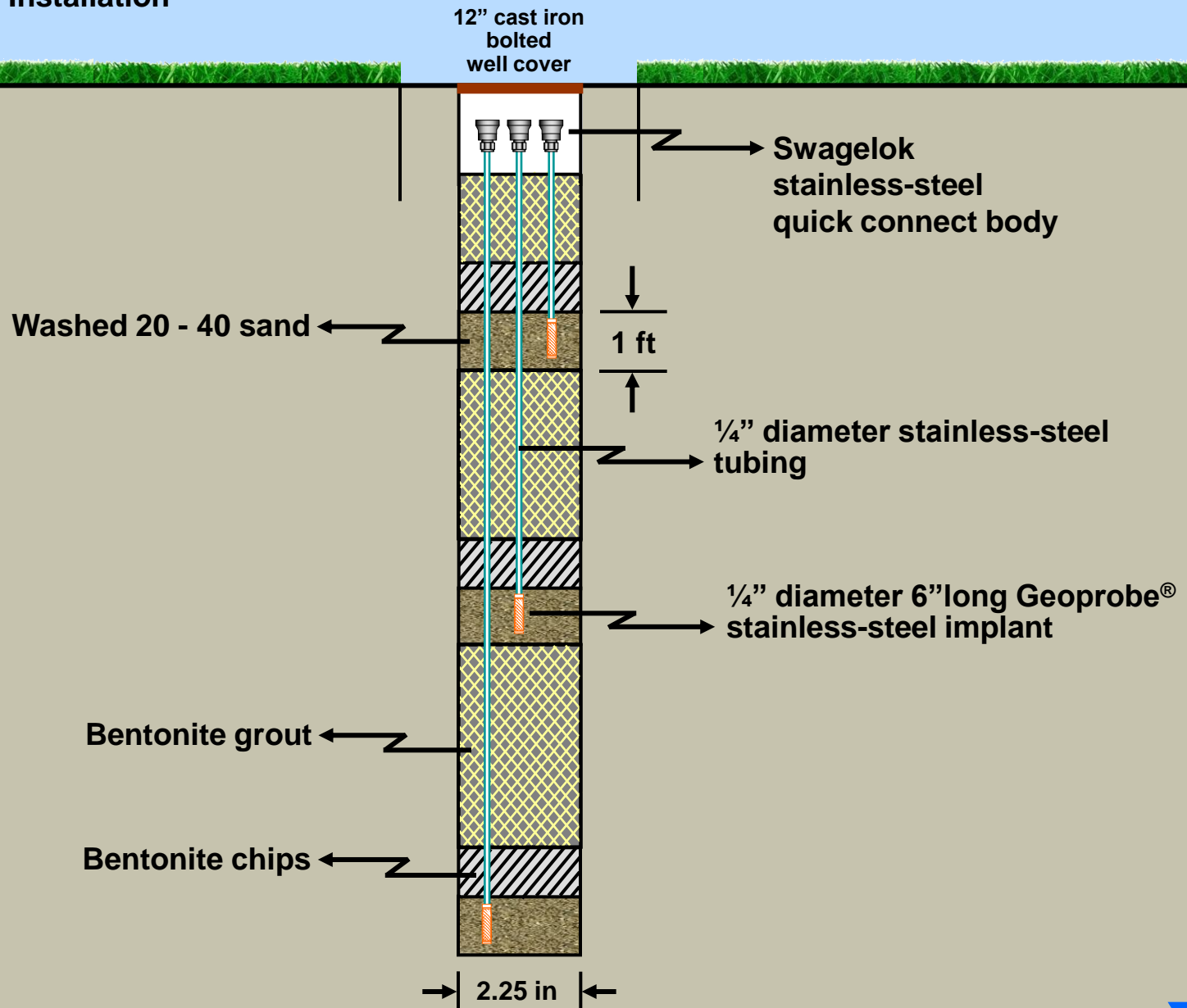
[illegible]



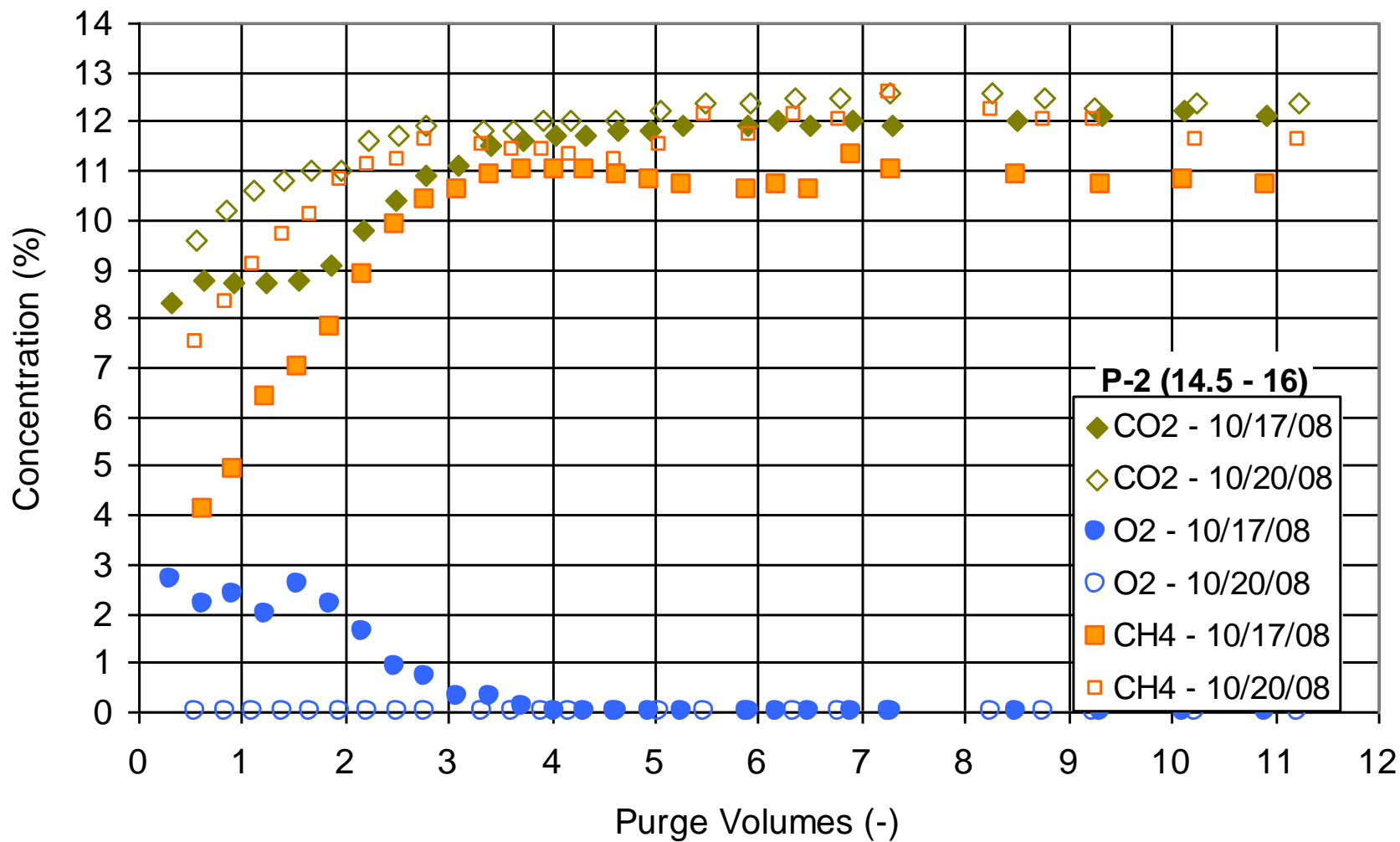
## *Leak Testing in Green River, UT*



## Vapor Probe Installation

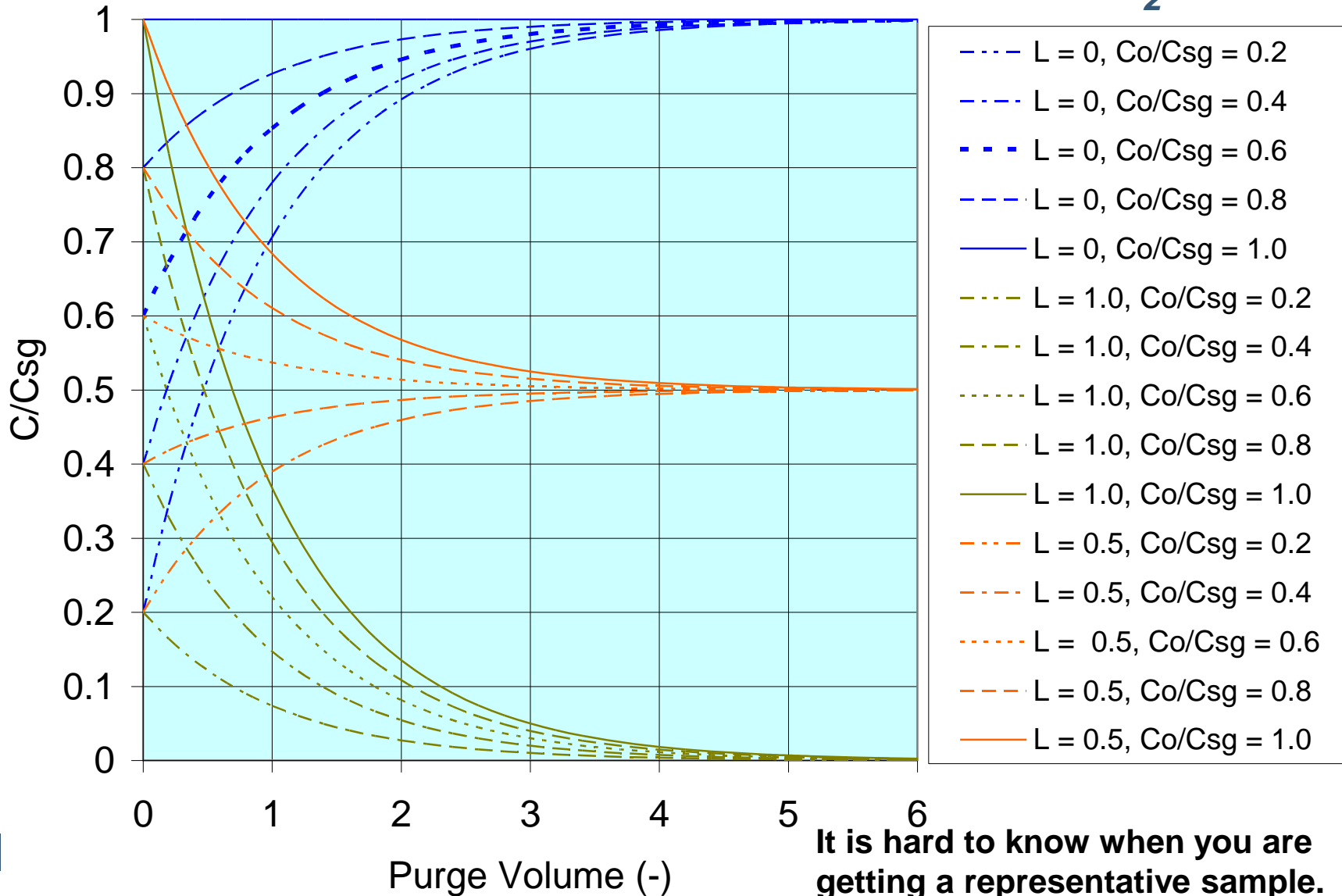


## Purge Testing

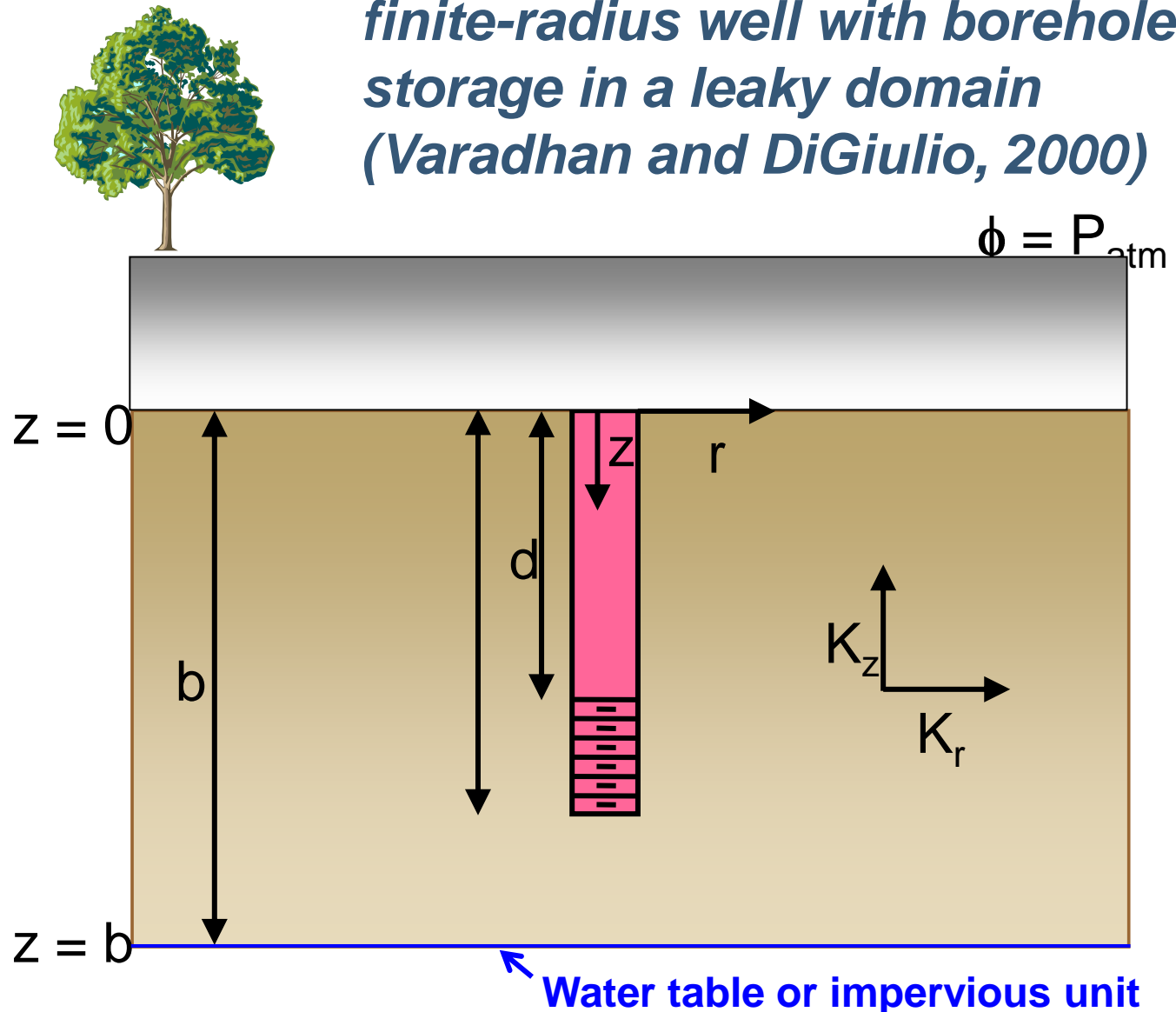




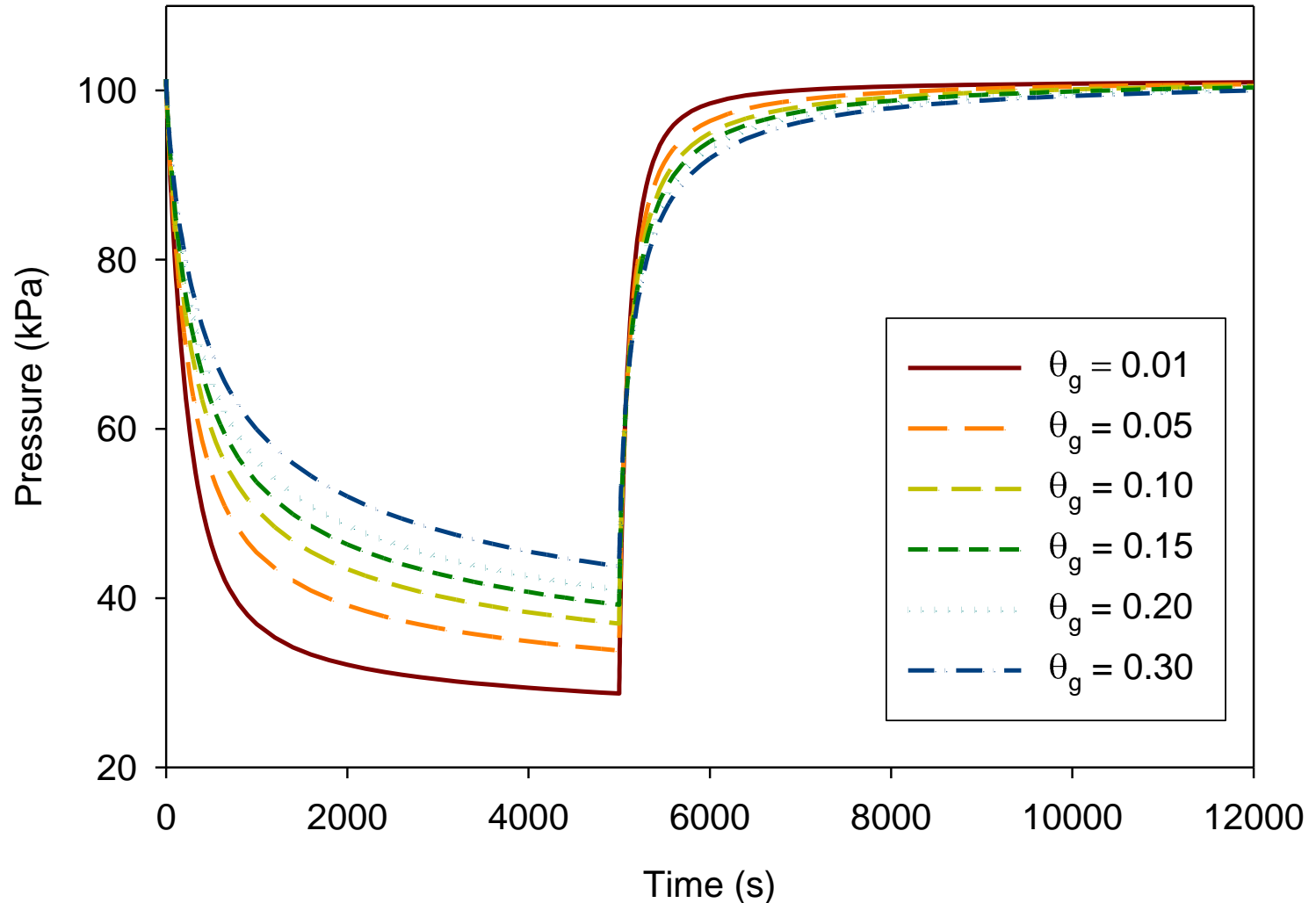
# Sample Concentration as a Function of Leakage, Initial Probe Concentration, and Soil-Gas Concentration for CO<sub>2</sub>



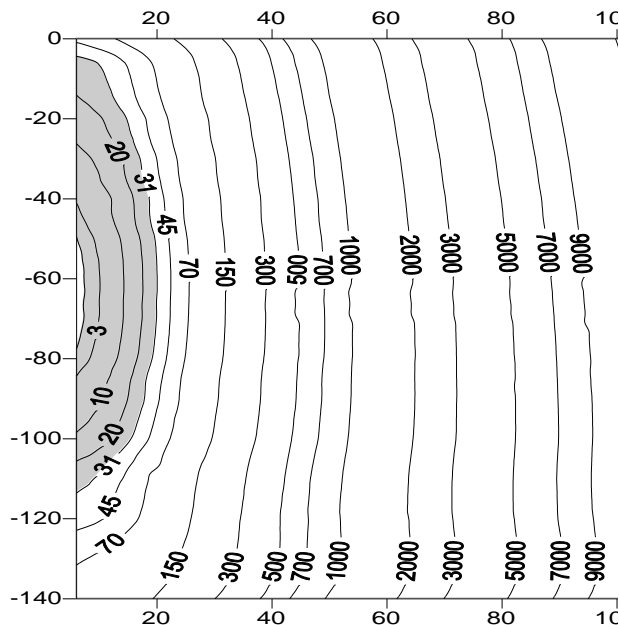
*Analytical solution for transient  
axi-symmetric gas flow for a  
finite-radius well with borehole  
storage in a leaky domain  
(Varadhan and DiGiulio, 2000)*



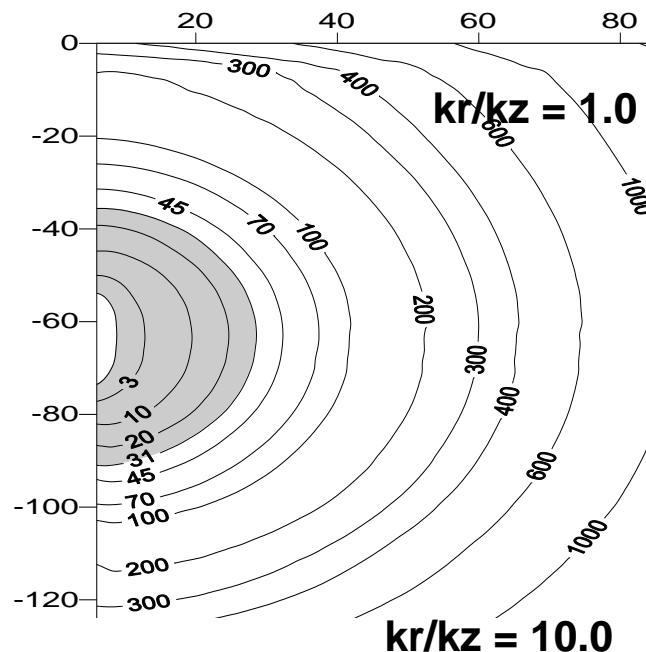
***Analytical solution for transient axi-symmetric gas flow for a finite-radius well with borehole storage in a leaky domain (Varadhan and DiGiulio, 2000)***



# Gas Flow During Soil-Gas Sampling



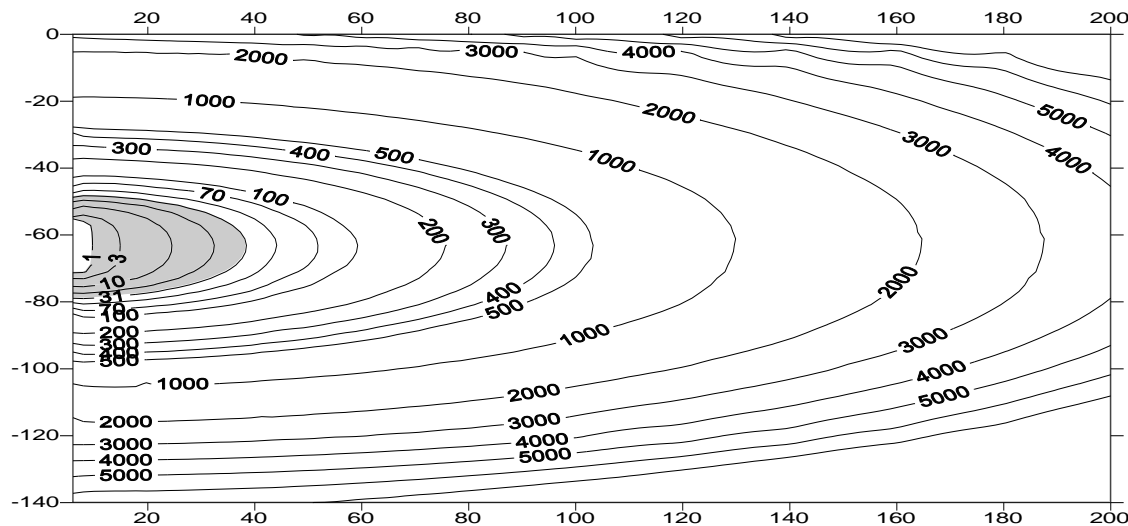
$kr/kz = 0.1$



$kr/kz = 10.0$

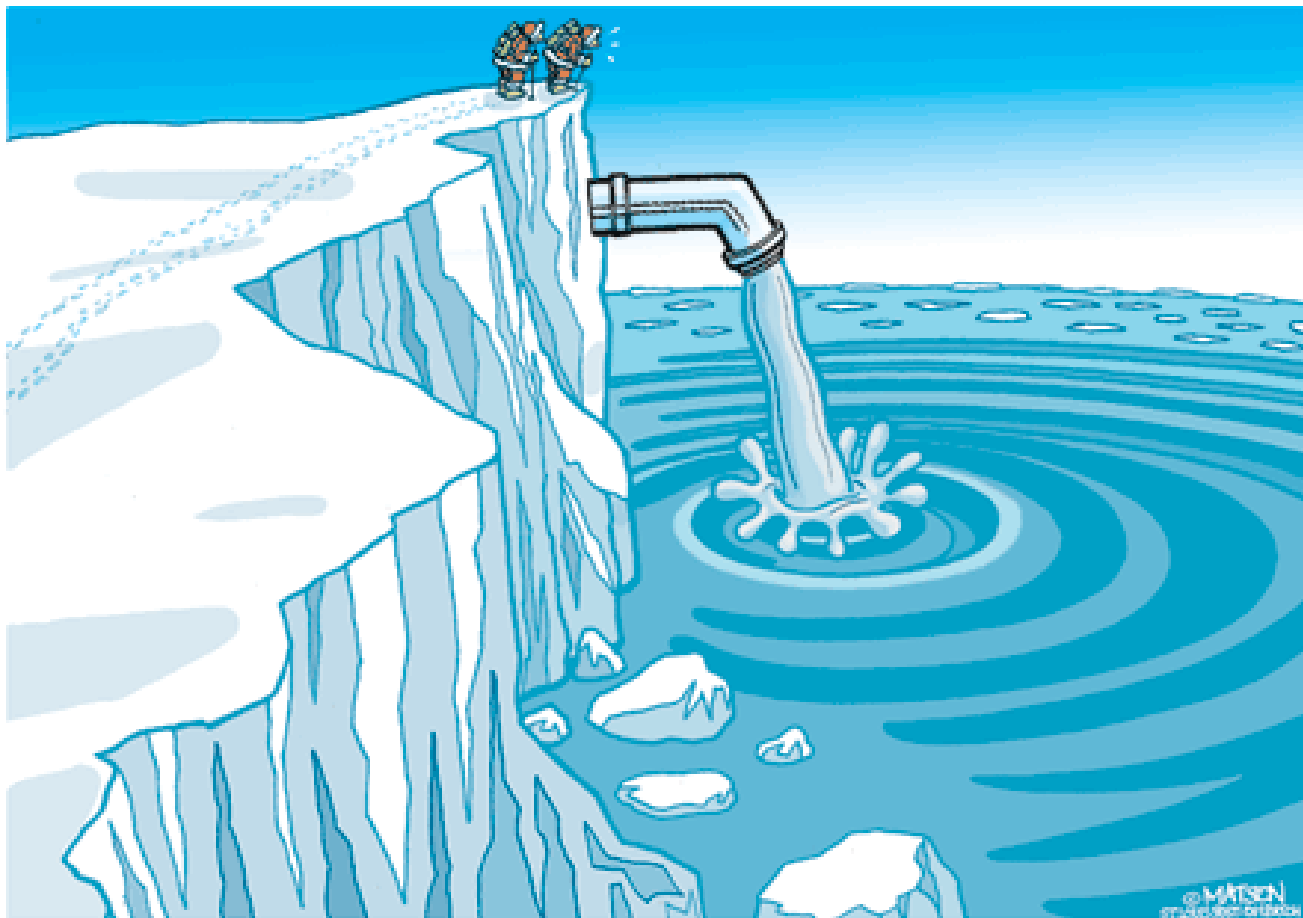
## Model Input for Particle Tracking

283.0	temperature (K)
-0.00641	pumping rate (300 sccm)
$1.1 \times 10^{-10}$	radial permeability ( $\text{cm}^2$ )
0.1	air-filled porosity (-)
520.0	thickness of formation (cm)
56.0	top of well screen (cm)
71.0	bottom of well screen (cm)
3.81	nominal well radius (cm)





# Questions?



**"HOW ON EARTH DO WE TURN IT OFF?"**

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